SUMMER 2011

An Innovative Project And Design Oriented Electrical Engineering Curriculum At The University Of North Texas

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ABSTRACT

We analyze and study the beginning of a new Electrical Engineering Department, supported by an NSF Departmental Level Reform award, within a new College of Engineering in the 21st Century and also describe the academic approach and influences of an innovative cognitive-based approach to curriculum development. In addition, the approach taken utilized open-ended projects distributed over the four years as pedagogical and motivational tools. Furthermore, the curriculum encourages a global-minded entrepreneurship approach as well as reports and presentations associated with learning activities.

The Electrical Engineering program begins by emphasizing the importance of recognizing how one learns and what one's preferred styles are, as well as the convergence and reinforcement of the classical domains of learning in active learning. In teaching this program we draw from affective, psychomotor, and cognitive self awareness to emphasize ethics, professionalism and engineering practices, creativity, acceptance of globalization, and consideration of social and environmental issues as part of a life-long learning career. Students graduating from this program are all well-received by industry and graduate programs.

Keywords: Learning to learn, project orientation, cognitive education, active learning.

INTRODUCTION: DEVELOPMENT OF A COLLEGE OF ENGINEERING

In 2003, the University of North Texas (UNT) encouraged by the professional and political leaders of the region, initiated a new College of Engineering (one of the few created in the 21st century) at what would become the North Texas Discovery Park. A Founding Dean was hired at the beginning of the year and assumed his duties in July. The new College had departments of Computer Science, Materials Science, and Engineering Technology transferred from the College of Arts and Sciences. Programs in Construction Engineering Technology, Computer Engineering, and Mechanical and Energy Engineering were added. But it was the creation and development of the Electrical Engineering (EE) Department that is most closely related to the Departmental Level Reform (DLR) program of the National Science Foundation (NSF).

In July 2003, a one-year planning grant (NSF-0343623) titled "A Project and Design Oriented Electrical Engineering Program" was funded by the EEC division of the Engineering Directorate of NSF. This funded planning proposal, containing the basic ideas for the then-proposed Department, provided time and resources for careful analysis, study, and development of the characteristic of this completely new Department, its faculty, students, facilities, and orientation. Considering the experience of others and our own objectives, we made several assumptions and reviewed case studies in order to plan for a genuinely 21st century innovative and relevant educational experience for our students.

As a result of this planning [1], a full implementation DLR proposal [2] was submitted (NSF 0431818) to the same NSF program and funded with cooperation between the EEC and EHR Divisions of NSF. This is the project, along with its evolution and its results that we describe in this article. This proposal included a broad-range comparative study of most of the leading innovative engineering programs in the US (with student-learning emphasis, in particular electrical). These included Olin College [3], Harvey Mudd [4], Rose-Hulman [5] and even some liberal arts approaches to motivational and student-centered education (e.g. Alverno College ([6], [7]). Today's programs offered at many universities including UNT are, as expected, quite different from what they were four years ago because of the continuous curriculum development and lessons learned. In this paper, we cover the most significant of those improvements.

ASSUMPTIONS AND STUDIES

The basic assumptions made by the team working on the definition of the program and the new EE Department were:

1. Emphasis on student learning integrated with dedicated faculty teaching would permeate all activities of the program.
2. Emphasis on student-originated design experiences of increasing complexity should permeate the four years.
3. Entrepreneurship and business practices would be part of the educational experience.
4. Students' involvement and motivation through hands-on activities leading to learning and self-reliance throughout the entire curricular sequence, rather than having a single experience in the senior year and prescribed laboratories entirely tied to classroom lectures.
5. Active learning, investigation, and teamwork were to be additionally emphasized and nurtured.

At the same time, we had the luxury of studying in a comparative manner the best practices in established EE Departments; we visited some of them, and invited academic and industrial leaders to contribute their ideas as reviewers to the program definition task.

OVERARCHING OBJECTIVES

There were three major overarching objectives in the design of the EE program, often suggested by our Advisory Boards and industrial consultants:

- *Enhance the students' enjoyment and success in learning*, with a better awareness of cognition, self-awareness, oral and written communications, and reflection.

To accomplish this task we included along with the engineering faculty a cadre of motivated High School teachers (mostly science and mathematics) and enthusiastic faculty from UNT's College of Education. They contributed a perspective of student adaptation to a more formal learning environment that also offered the potential for personal growth and self-understanding.

- *Instill in the students' performance a sense of practical engineering reality* because we wanted to make the experience as useful and durable as possible after graduation. This carried the underlying emphasis on life-long learning and individual responsibility for his/her own overall education.

We used several approaches to meet this objective:

a. extensive use of open-ended projects (as opposed to tightly prescrib
b. strong emphasis on teamwork and team projects
c. continued emphasis on professional presentations (oral and written) throughout the four year curriculum.

d. endorsement and recognition of professional society activity as a mechanism for networking, keeping up with the state-of-the-art in the profession and contributing to social and civic activities.

- *Promote innovation and motivate commitment to their personal growth as engineers*

We wanted a curriculum in which the students had a vested interest in self improvement and that was alive with change and motivation for personal enhancement. The project-oriented approach satisfied a good deal of motivation, support and cohort formation as part of their eight semesters of team projects. Lectures and reading materials on creativity and professionalism, patents and entrepreneurship were included, mixing technology and its application to many aspects of professional life.

We approached these overarching objectives with a three-pronged strategy: 1) the Learning-to-Learn (L2L) approach, to enhance success in learning, 2) the introduction of business courses oriented toward entrepreneurship and globalization, and 3) a more open-ended approach to projects, courses, and laboratory work to get closer to industrial practical reality and promote innovative reasoning and motivation in the student's work. We also consider other complementary objectives (such as program accreditation, dissemination through interaction with High School faculty, and continuous improvement.)

Learning to learn (L2L)

This ambitious non-classical freshman course had a number of objectives within its brief 2-credit semester hour span. It has been an evolving course and significant continuous improvements from student and faculty feedback have been incorporated in every new offering. The syllabus of the course is provided in Appendix A. We mention below the most salient aspects, as this course is the "signature" course of the curriculum. We emphasize that the course has evolved due to the contributions of many people. Among these contributions, we can cite:

a. Cognitive mapping

We put significant emphasis on the self awareness of cognition in the L2L course that permeates, without conflict, other aspects of the curriculum including correlation with the ABET Course Learning Objectives. The fundamental work of Bloom [9], and his work with others [10], is reported in the coverage of Atherton [13] following Anderson and Krathwohl [12]. An interesting relationship noticed in this course is the analogy between the engineering design process and Bloom's cognitive domain pyramid (Figure 1). We used the Institute for Human and Machine Cognition [32] software and procedures often.

b. Learning styles

We followed the work of Dr. Richard Felder [24], [25], [26] and decided that his questionnaire approach to determining the learning styles preferred by each student was the most effective and

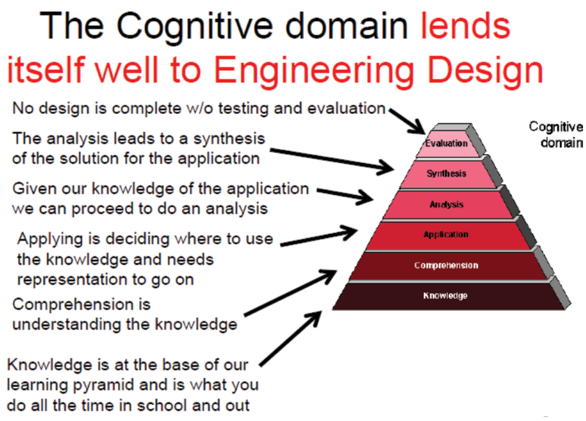

Figure 1. Bloom's steps in his Cognitive Learning Domain parallel those of Engineering Design.

practical. It became one of the early pillars of our approach and has been a revealing exercise for the students.

c. Hands-on approach

As a motivational tool and as a mechanism for self-reflection [33] in their manner of learning, we introduced a very simple sensor circuits laboratory kit that the students could learn rapidly and easily. The kit included choices of sensor experiments in Mini-Projects and a final experiment that was an open-ended one. In a sense, these Mini-Projects (three of them are increasingly less prescribed and the final one is open-ended) set the stage for the other seven projects in later courses in the EE curriculum. While today the concepts of Project Orientation are well defined and popular, it is not presumptuous to say that in the decision phase of our planning pre-2004 curriculum we were pioneers in espousing a an open-ended project approach distributed throughout the entire curriculum. "Just-in-time" learning was a natural result of that approach because students learned and reasoned on the spot when they had an immediate new problem to solve. This approach was developed independently during an NSF planning grant [1] preceding the implementation grant [2] although, as we have learned, the term had been used before as an experimental "radical departure from conventional curricula" [51]. The term had been used also in other previous educational approaches as well as in the original Toyota inventory approach to manufacturing.

d. Oral and written communications

One of the industrial clamors over the years had been for engineering graduates with better communication skills. We found it to be a well-justified request. In this course we ask that every Mini-Project be associated with a short engineering report and a 15 minute presentation by each member of a team of three students. The functions of the team members in deciding, assembling, testing, etc during the project and in the reporting and presentation rotated in each of the three Mini-Projects and shared among all team members in the Final Project, therefore all members practice effective communication skills.

e. Teamwork

It is well established [18] that members of a student cohort have a better chance of success in their academic endeavors if they establish lines of communications and get to know each other. While impossible to force the students into this modality, we make them realize the advantages of working as a team, helping each other but doing their individual work. Because of the rapid pace of the course, the students learn time management, planning, and ethics in a practical sense during these small projects.

We found it possible to pack lectures and experiments by moving to newer educational technologies that we describe in Appendix A.

Involvement of Education Faculty and High School Teachers

We decided early in the curriculum design phase that our program would be open not only to the traditional University Core Course teachers but also to some of the non-traditional teachers for engineering education. Education faculty members were enthusiastic about participating in the L2L course. They were and continue to be essential in carrying out an independent auditing view of assessing our curriculum and other activities. High School teachers participated in the teaching of some aspects of the L2L (for example in the lecture on transitioning to college) and were a welcome bridge in helping the students' progress to the University environment from High School in a friendly way. They brought their experience to ease and explain the differences from High School to higher education as needs for adaptation and responsibilities. They established a continuing informal advisory link with the professors teaching the L2L course as well as with the students taking it.

The involvement of faculty external to the College of Engineering was also a dissemination strategy that worked very well. We became involved in a High School level robotics competition that allowed us, along with High School teachers involved in our program, to convey some of the concepts of L2L in the competition.

ABET's Program Outcomes following the Learning Objectives

In accordance to ABET's process for accreditation of EE programs, as specified in [49] and [50], we followed "Criterion 3", informally known as "a through k" or "a-k". For this purpose we related the expected Program Outcomes (PO) as listed in Appendix B with the course learning objectives (CLOs). It is not expected for a single course to cover all of the 11 POs required of a program, nor that the CLOs have a one-to-one correspondence with the POs. We mapped eight POs into seven L2L CLOs. The course is organized in learning Units which contain lectures, readings, project support materials, and assignments. During the last course offering all Units were available to the students in a Learning Management System (Blackboard Vista, which we will describe in a later section). This facilitated achieving a "blended instruction" [19] that stimulates life-long learning (as suggested in ABET's Criterion 3 in our Appendix B). We present the CLOs to the students along with an abbreviated explanation of their relation to the contents of (a)-(k) of ABET's Criterion 3 as follows:

CLO-1 Help students recognize their learning styles and enhance their understanding of the learning process—related to ABET's (i) which implies the recognition of the need for, and an ability to engage in life-long learning in an effective manner through recognition of their learning styles. This is demonstrated in the first class as part of the course orientation in Unit 1; we present the styles inventory and the students individually take and discuss Felder's diagnostic questionnaire, explained in [27] and available in [28]. We also cover aspects of motivation and responsibilities in Unit 5. In Unit 3 we delve into some practical aspects of cognition such as memory, knowing and understanding and their differences, how to represent knowledge, symbols for communication, Bloom's taxonomy of learning domains and some superficial aspects of self-reflection. In Unit 7 we introduce some aspects of logical conceptualization that should be helpful in organizing presentations and technical processes in writing and design; we have illustrated the cognitive map of our course in Figure 2 in this manner.

Unit 10 of the course caps the cognitive emphasis with a review of the relation between written and oral statements and their critical analysis and evaluation. Assignments include two controversial

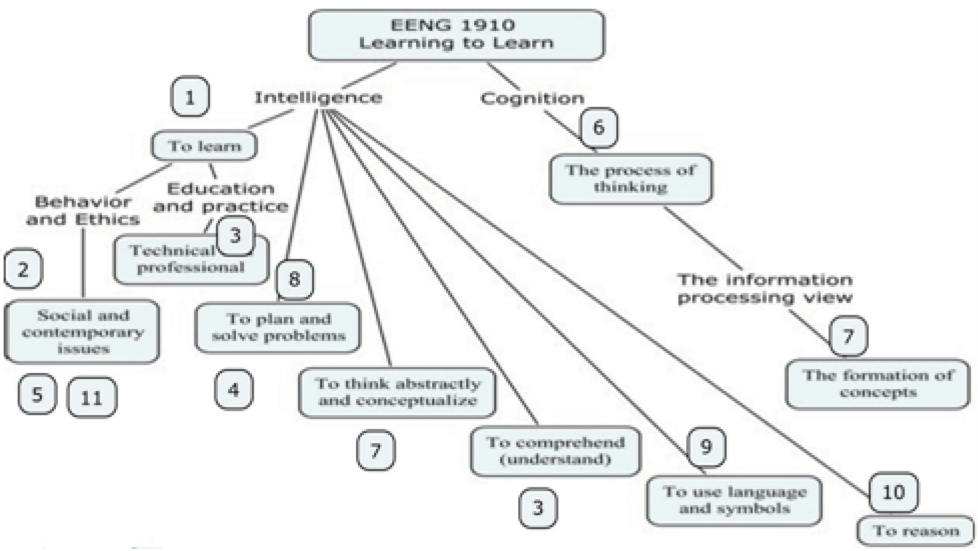

Figure 2. An example of a concept map relating cognitive concepts to units of the course where they appear.

issues to consider critically. The combination of the materials in Units 1, 3, 5, 7 and 10 justifies our claim of a strong practical emphasis on diverse aspects of cognition, as we find them applicable to the objectives of the course.

CLO-2 Enhance students' ability to integrate design concepts, analytical thinking, and problem-solving skills—related to ABET's (c) and (e) which implies abilities to design and conduct experiments, as well as in identifying and formulating data in solving an engineering problem. In a very introductory and gradual manner the Mini-Project sequence is an active learning and critical thinking exercise requiring answers to questions in class and in the report. The Mini-Projects involve aspects of design, particularly evident in the Final Project. That is the reason why we consider this course with its four small projects to be the introductory Project I to the sequence of the seven subsequent semester-Projects in the EE curriculum (Appendix C). In the lecture portion of Unit 4 we deal with the sequence of analysis and simulation, synthesis and testing, and evaluation and verification in a rapid succession. In Unit 6 we dedicate more time to the engineering design as a process and assign a practical application to be designed. In Unit 8 we suggest a process of problem solving and give examples as well as cover some classical approaches to creative thinking and general problem-solving skills.

CLO-3 Develop students' appreciation for engineering as a profession and the required professional ethics—related to ABET's (f) which demands understanding of professional and ethic responsibilities. Early in the course (in Unit 2 and whenever we can reference it in the other lectures) we address professionalism and ethics issues. We discuss in an electronic open forum the difference between a skilled worker and a professional (competent with a body of knowledge and practicing an established code of ethics). We have posted the IEEE Code of Ethics at the entrance of the Department, and we discuss it in class, as well as a few related case studies. We also cover plagiarism and unethical class conduct. One of the most effective parts of Unit 2 is the presentation by the student leaders of our IEEE Student Chapter and their invitation to the class to participate in their activities and meetings as well as providing information about the IEEE.

CLO-4 Enhance students' abilities to work in teams—closely related to (although more restricted than) ABET's (d), which implies working on multidisciplinary teams. This is an accepted industrial and academic trend toward "open innovation" involving focused collaboration in solving a problem of common interest. We should notice that the overall DLR grant has evolved during its course based on this principle and those meetings with NSF and other EE DLR grantees are an analog to what we teach students. We describe briefly some of our very successful DLR project collaborative efforts in a section of this paper. So far this has been a successful experience in practically all cases as evidenced by the student evaluation of this CLO in annual anonymous evaluations: near half of the class consistently rate the team experience among the two top highest improvement ratings and relate the success in their Mini-Projects to teamwork. This team formation and work is done to carry out the Mini-Projects utilizing a Sensorlab kit from Radio Shack that is simple and self contained but it also stimulates social interaction in class that lasts beyond the course. The Course Outline indicates the different initiation dates and deadlines of the Mini-Projects.

CLO-5 Enhance students' abilities to prepare and deliver oral presentations and write technical reports—a very successful part of a project-oriented course and curricula addressing ABET's (g): an ability to communicate effectively. This objective is satisfied in two ways: the first and most practical is related to each of the oral and written presentations (and the suggestions, rubrics see [48], and post activity feedback) for each one of the four Mini-Projects in L2L; the second is in the considerations of Unit 9 in which we cover a variety of aspects that can make a report or presentation more or less effective. The students seem to benefit and improve in their oral and written communications from this and other project courses as they go through our curriculum that culminates in two very open-ended senior projects of independent teams resulting in excellent design products.

CLO-6 Develop students' awareness of globalization issues and impact of engineering solutions in a global and societal context—closely correlated with ABET's (h): the broad education necessary to understand the impact of engineering solutions in a global and societal impact. In the last course offering, because of a holiday the course was cut short by one class period. We handled this problem by successfully integrating the class discussions related to CLOs 5 and 6 with timely global issues. Since the issues change periodically, this approach has been used as needed.

CLO-7 Develop students' awareness of contemporary environmental and societal issues and their future roles as engineers to contribute solutions—similarly oriented to ABET's (j): knowledge of contemporary issues, in particular, but involving issues related to the previous outcome (h) since these issues are global. The global and societal issues are clearly intertwined as shown in the three segments of Appendix D.

Business courses

There have been strong interactions between the College of Engineering (CENG) and the College of Business (CoB) in general, and between the EE Department in the former and the Management Department in the latter. This has occurred both in a formal academic approach and in a more informal competitive environment of entrepreneurship. Influenced by the strong entrepreneurial approach of Olin College, we decided to require two courses, taught by experienced CoB faculty, related to management and entrepreneurship. The two courses are:

MGMT 3830 Operations Management (3 hours): Management of production emphasizing industrial enterprises; production objectives; design and improvement of processes, work methods, and physical facilities; use of measurements and standards; production planning and control; quality control; budgetary and cost control; materials management.

MGMT 3850 Entrepreneurship (3 hours): Initiation of new ventures and approaches to growth of existing firms through opportunity recognition, innovation, and change. It emphasizes developing effective entrepreneurial skills and behaviors. The course includes preparation of a comprehensive business plan. Open to non-business majors.

Additionally, the endowed Murphy Center for Entrepreneurship in CoB annually sponsors "The New Venture Creation Contest" (NVCC) to give UNT students the experience of soliciting start-up funds from early-stage investors and venture capital firms. The competition involves real-world opportunities to learn what's required to successfully launch a new venture, particularly attractive to students working on open-ended projects in EE as part of their degree requirements. To complete business planning education students are mentored by investors and experienced entrepreneurs, and they network with local business leaders. Students attend periodic educational seminars in specialized business practices sponsored by the Murphy Center. As part of the competition the judges provide high-quality and detailed feedback to the competitors who benefit greatly by the experience whether they win part of the $50,000 annual prizes or not. Some of our EE students participate in this annual competition as seniors with other like-minded industrial technologists and get exposure for their creation through the media.

Projects, Courses, and Laboratories

Given the project orientation, the courses and laboratories were inspired by the spirit of the proposed NSF Department Level Reform, which resulted in the EE Department creation at UNT. We have maintained websites for the projects, courses, publications and other activities associated with the DLR to chronicle the evolving nature of the educational approaches. The web pages that describe courses and projects are referenced in [8]. We have given details on the Project I L2L course because it sets the pace for the other projects and the learning habits of the students. A brief description of the eight project courses are shown in Appendix E. They are:

- EENG 1910 Project I Learning to Learn (2)
- EENG 1920 Project II Introduction to EE (2)
- EENG 2910 Project III Digital System Design (2)
- EENG 2920 Project IV Analog Circuit Design (2)
- EENG 3910 Project V DSP System Design (2)
- EENG 3920 Project VI Modern Communication System Design (2)
- EENG 4910 Project VII Senior Design I (3)
- EENG 4990 Project VIII Senior Design II (3)

It is important to emphasize though that adoption of a project-oriented curriculum does not imply deemphasizing the classical lecture courses. The distribution of the project courses (one per semester) is shown, along with other EE lecture courses and general education courses (in a suggested program with the latest approved curriculum) in Appendix C.

Please notice our balancing between laboratory work and classroom theory and modeling. The eleven lecture courses (within EE), including two elective courses, are described briefly in Appendix F:

- EENG 2710 Digital Logic Design (3)
- EENG 2610 Circuit Analysis (3)
- EENG 2620 Signals and Systems (3)
- EENG 3510 Electronics I (Devices and Materials) (3)
- EENG 3410 Engineering Electromagnetics (3)
- EENG 3710 Computer Organization (3)
- EENG 3520 Electronics II (Circuits & Applications) (3)
- EENG 4010 Technical Elective I (3)
- EENG 4710 VSLI Design (3)
- EENG 4010 Technical Elective II (3)
- EENG 4810 Computer Networks (3)

Furthermore, in September 2007, we initiated a MSEE program. Multipurpose (undergraduate projects/graduate research) laboratories were established and well equipped with modern instrumentation to serve all the students. These selective laboratories provide specialized equipment for projects, MS theses, and independent study. The multipurpose laboratories are listed with a brief description in Appendix G. They are:

- Analog, RF, and Mixed-Signal Design Laboratory
- Autonomous Systems Laboratory
- Communications and Signal Processing Laboratory
- Computer Aided Design (CAD) Laboratory
- Speech, Music, and Digital Signal Processing Laboratory
- Vision, Robotics, and Control Systems Laboratory

The integrated combination of the student motivation generated by the projects, the fundamentals presented in the classroom, the real life input of presentations, the time management and social interaction in teams, the introduction to management, entrepreneurship and financing, and the use of up-to-date equipment and CAD tools, provided excellent results. General acceptance of these successful approaches resulted in the positive accreditation decision granted by ABET to the EE program in 2010.

ACCOMPLISHMENTS OF THE DLR AWARD AT UNT

The impact of this award on the whole Electrical Engineering curricula and its transformational influence can be gleamed by the substantive entries about the award in the departmental website [8]. The best summary of these accomplishments may be described in one particular sentence:

"The DLR grant enabled the establishment of a mature modern, innovative project- and student-oriented Department of Electrical Engineering in an incredibly short period of time."

An important spinoff of the ideas generated from the early experiences [15] of the DLR activities resulted in an NSF sponsored regional workshop in the Southeastern region held in Dallas on the "Integrative Computing Education and Research (ICER) Preparing IT Graduates for 2010 and Beyond." This regional workshop, attended by High School, Community College, and University IT teachers, emphasized the broader impact of the cognitive, project-oriented, and entrepreneurial aspects of the DLR approach applied to Information Technology and our blended approach to education. The industrial concept of using "just-in-time" inventory in manufacturing, transformed educationally to the active project-oriented learning approach [16] [17] of our DLR award, having appeared earlier in other literature [51], are now well accepted in educational circles.

RECENT DEVELOPMENTS: USE OF TECHNOLOGY TO AID OUR APPROACHES'

The use of modern educational technologies continues to allow improvement of the materials presented, refined along with the introduction of the hands-on Mini-Projects during the evolution of the L2L and in other courses [8].

In the Spring 2009 offering of L2L we started using a Learning Management System called Blackboard Vista, supported by UNT's Center for Learning Enhancement, Assessment, and Redesign. We intended to improve student satisfaction, because this tool allows availability of presentations, reference materials, assessment tools, additional web and interactive resources for use by the students enrolled in the class and course management tools for the instructor. However, the degree of course satisfaction has varied over the years from no satisfaction ranging from 18 to 30% and has been worsening as we increased the number of assignments and assessments and decreased by one the Mini-Projects. The transformed blended instruction course [11] evidently requires more background information on the challenges of off-campus accessibility. Perhaps we have gone beyond the tolerance of the students on the assessment tools. We introduced an additional assessment tool effective in gauging in real-time the students' understanding of the concepts. We introduced the use of "clickers" or small response keypad radios linked to a computer receiving unit in the room utilizing

Turning Technologies software [21]. The result was a dual system in which the same presentation is available for the student response units in the Turning Point system for classroom polling that is available for student use outside the classroom utilizing the facilities of Blackboard Vista. Refinement in the use of these educational technology tools is obviously necessary and experimenting with multiple choice questioning is a delicate educational art.

During the Summer 2009 we provided every faculty member of the Department of Electrical Engineering with a PC tablet loaded with the Camtasia software system [22] recommended by a peer DLR institution PI. This allowed the creation of audio-visual short clips (with a pen sensitive tablet computer and voiceover information) over any editable or non-editable screen background. Some of this material has been already incorporated in the students' resources in Blackboard Vista.

We anticipate that the use of these educational technologies will make all the Project courses in the curriculum more meaningful and interesting to the students.

INDUSTRIAL, HIGH SCHOOL AND PEER INSTITUION COLLABORATION, DISSEMINATION AND LESSONS LEARNED FROM OTHERS ON ENGINEERING EDUCATION INNOVATION

It is important to emphasize that we have shared our experiences with others and received their advice as well. This has been a very important and rewarding activity and we report it here as part of recommended best practices.

A number of presentations and published papers ([41], [42], [43]) allowed dissemination and feedback on intermediate results of the pedagogical approaches described in this paper. On October 26 and 27, 2005, in Dallas, we conducted the NSF-sponsored Southeast Region Integrative Computing Education (ICER) conference on "Preparing IT Graduates for 2010 and Beyond." This conference was part of six parallel regional ICER conferences concerned with continuing the vitality of undergraduate computer education in the following five to ten years. During the Dallas conference many of the same pedagogical approaches of cognition, entrepreneurship and project-orientation (cited before in the context of Electrical Engineering and archived in [8]) surfaced as promising approaches applicable to other rapidly changing technological areas. The final report of the conference [45] conveyed the broad scope of the horizon of the Computer, Information Science and Engineering (CISE) NSF Directorate. This scope was depicted in Figure 3 which included the same concerns for Electrical Engineering education, along with concerns for sister computer-oriented disciplines down to users.

The PI and co-PIs of the subject DLR grant described here surveyed the attendees and author 2, as a co-PI, made a presentation on this topic [15] generating valuable audience input and suggestions, such as increased used of multimedia and active learning. A paper and presentation provided a status of project progress in 2006 was made and archived at the ASEE Gulf-Southwest Conference that year… Also archived is another paper presented at the International Conference on Engineering Education (ICEE 2006, July 23–31) which provided feedback from a broad audience on the use of our methodology to the beginning logic design course [43]. Finally, in the same year and archived, we presented "Work in Progress: An Innovative Electrical Engineering Program Integrating Project-Oriented and Lifelong Learning Pedagogies" at the 36th ASEE/IEEE Frontiers in Education Conference in San Diego, October 28–31 [41].

These early presentations provided invaluable peer educators input to our projects.

As part of the award, we anticipated three sets of interactions with external groups (not including dissemination efforts):

1. We anticipated recruiting experienced industrial electrical engineers from the significant pool in the surrounding area to work as adjuncts in our project sequence. Although we had some excellent experiences with consulting or retired engineers, we were surprised to find out how difficult it was to maintain the relationship semester after semester, which imposed a burden on the departmental administration. It was also difficult to make the recruited adjunct faculty, with some notable exceptions, realize the importance of relating the fundamental principles to their industrial applications. This has been a difficult aspect of the project-orientation to sustain in the long run, but some members of the EE Department Advisory Committee lived up to the original expectations.
2. We routinely interact during the course of our annual recruitment efforts in High Schools and Community Colleges with teachers in a wide net of institutions and also as part of a prize-wining High School robotics competition that we sponsor. These teachers participated in assisting us with different aspects of our curriculum and at times, depending of their specialty and background, with the development of our early projects. They have been particularly attuned to our cognitive approaches and embraced them enthusiastically. We considered this a STEM enhancement and a dissemination function during the course of the award. Regionally, we

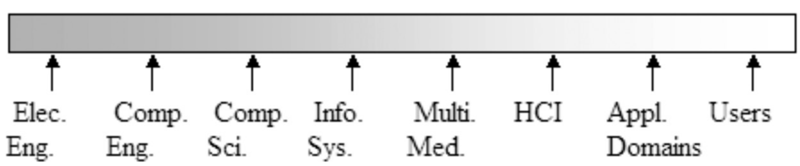

Figure 3. The scope of related disciplines to which the concepts of the DLR approach were considered applicable and beneficial by the ICER workshop.

engaged with sister institutions such as Texas Woman's University (facilitated by proximity) with which we established a joint program between Mathematics, Computer Science and Electrical Engineering with dual degrees in a 3/2 years arrangement attracting women and minorities.. We also interacted with other DLR granted institutions, which reported similar approaches to the longer than anticipated duration needed to implement a sustainable innovative program in EE with strong project orientation.

3. The impacts of the DLR "philosophy" were more coincident throughout the nation and disseminated to other related disciplines (see ICER references [44] [45]) as we explain:

a. The DLR awardees met as a group for the first time at a workshop in the NSF facilities in Ballston, VA on May 15, 2008 to exchange insights such as the needed period to judge longitudinal performance and impact of our common project-oriented approaches. A common pragmatic concern was the sustainability of the required intensive faculty and technician labor. *Admitting that educational change must come from faculty, the group agreed that institutionalization requires administrative support*. Many conclusions of this workshop coincided with the Science and Technology Policy Institute (STPI) comprehensive evaluation of the DLR program. On October 2008 STPI issued Part I of the study on Synthesis Evaluation of the DLR grants [6], soon followed by Case Studies and Dissemination Outputs.

b. On February 1-3, 2009, an "Engineering Education NSF Awardees Conference" took place in Reston, VA; this event was an excellent opportunity for cross-fertilization via presentations and poster sessions among the DLR and with the grantees. The important impact of the program was evident in a new trend toward *revitalizing Electrical Engineering education with more open-ended projects*.

c. On March 31-April 1, 2009 the "Engineer of the Future, 2.0" meeting took place at Olin College in Needham, MA, a private institution that we had followed for *its innovative educational/entrepreneurial approaches*. The presenters emphasized very interactive engineering education transformations based on classroom interactivity, and we participated in the exchange with common interests. This was a very passionate meeting with unusual presentation styles and strong student participation. The Alliance for Promoting Innovation in Engineering Education ($APIE^2$) issued "A Transformation Proclamation" signed by the attendees. For a visual impression of this high-intensity meeting see [40].

d. On May 22, 2009, in anticipation of the end of the EE DLR award at UNT, we convened a meeting of grantees with similar goals from Oklahoma State University, Kansas State University, University of Utah, Duke University, UNT, and representatives from STPI. The meeting resulted in a plan to *make sure that the momentum of the work so far was helped to be sustainable through collaboration* [20].

e. Independently, a Chautauqua Short Course, May 27-29, 2009, titled "Enhancing Student Success through a Model Introduction to Engineering Course" run by Dean Emeritus Raymond B. Landis of California State University, Dominquez Hills espoused similar concepts of *student team interaction in projects and the affective aspects influence on behavior modification and commitment to learning*. We discovered strong commonalities not only in his techniques to motivate and guide engineering students in general but also in his excellent textbook on "Studying Engineering" [23] with our L2L course

These interactions have been *invaluable in validating our approaches and positive assessment results and finding out that the null hypotheses often repeated them*selves: 1) team efforts in active learning and reporting greater learning and commitment results; 2) consideration of entrepreneurial and ethical, professional and social issues, bringing greater awareness and attention to the human and physical environment; and 3) greater effort in emphasizing learning as a multifaceted cognitive activity with different learning styles making the student self aware of how to improve his/her learning by capitalizing on individual styles.

ASSESSMENTS

Pretest and post-tests comparison in the L2L course showed consistently two interesting aspects: 1) the students overestimated their knowledge of the subjects that were the focus of the course learning objectives and underestimated the workload of the course, as judged by the instructors, and 2) not surprisingly there was a strong similarity between the statistics of the impact of the course and the grade distribution in class over repeated offerings. The first of these two conclusions is the improved ratings by different panels of three professors on presentations and reports as the course progresses, the association with other students and professional student organizations, and the observable use of conceptual maps [32] and visual tools in group studies and demonstration/presentations in other undergraduate project courses later on. The second relates probably to the degree of academic performance and how much the student has learned.

The columns of Table I correspond sequentially to the seven CLOs listed previously in this paper. While the average responses show varying degrees of improvements, there is concern with those who claim no improvement took place. Table I is the result of an anonymous typical class survey. The students' interest in their learning styles is noticeable. A brief statistical analysis of the survey reveals that the Felder [24],[25],[26], study of the learning styles shows the most significant improvement of any other topic (over twice the mean of the second highest rated category) and that the professional ethics are also highly rated. The material on environmental and social issues was not so effective, possibly, because it was the last one and was mixed with a number of administrative instructions. The surveys were anonymous and we did not attempt to correlate the course grade with the 20% that indicated that on the average the course resulted in no improvement effect in their learning. We cannot determine the correlation but we observe that 20% of the class received D or close to D grades. The composite nature of the grade (assignments, assessments, in-class questions, presentations and reports) may reflect the dedication of the student to the subject.

The variances on the five-point scale of the seven CLOs in Table I are:

[429.4 105.87 240.1 61.89 240.1 55.9 .212.5]

which with one exception correlate negatively with the lowest effectiveness ranking in the evaluation. An analysis of the covariance matrix does not reveal any other significant clues.

Internal assessment of the program has been ongoing and augmented by reviews conducted by external education professionals. The assessments have found that the total curriculum developed in this program incorporates project-based learning, learning to learn, and entrepreneurship all of which map well to ABET outcomes. Students are developing the skills, knowledge, and behaviors that ABET expect them to acquire as they progress through the program. These findings are well documented throughout the progression of projects completed by the students as well as the oral and written presentations that accompany each project.

The program has been assessed as a summary of its formative improvements and now in its summative processes. Formative assessment involved the aggregation of individual CLOs into POs as the program evolved. The degrees of achievement of CLOs of individual courses have been measured using carefully prepared evaluation rubrics that are shared with the students at the beginning of each semester. The rubrics have five levels of achievement for each CLO along with a description of what it means to achieve a particular level in that CLO. Student performance data gathered using these rubrics can be classified into two groups: i) direct assessment data, wherein the instructor

Improvement from start of course	Learning style (CLO 1)	Design concepts (CLO2)	Prof. ethics (CLO 3)	Work as a team (CLO 4)	Reports and presentations (CLO 5)	Engn. & global issues (CLO 6)	Environmental and social issues (CLO 7)	Mean for each level
To a much greater degree	14.81%	10.71%	6.90%	20.69%	0%	10.34%	5%	9.78%
To a great degree	55.56%	21.43%	31.03%	27.59%	6.90%	27.59%	15%	26.44%
To some degree	18.52%	35.71%	41.38%	13.79%	31.03%	24.14%	40%	29.22%
To a small degree	3.70%	10.71%	13.79%	10.34%	34.48%	13.79%	10%	13.83%
No change, the class had no effect	7.41%	21.43%	6.90%	27.59%	27.59%	24.14%	30%	20.72%

Table I. Results from anonymous post-test survey.

fills in the rubrics for individual students based on the examinations, project reports, assignments, etc., and ii) indirect assessment data, wherein the students fill in their level of achievement (on a five-point scale) in each CLO in a self-assessment survey. Both the direct and indirect measures of degrees of achievements of the CLOs are computed as the average levels of achievement among the students taking the course. For computation of the degrees of achievements POs in a course, a CLO-PO mapping table prepared by the instructor is used, and the PO achievement degrees are computed by averaging the degrees of the CLOs, if any, mapping onto a PO. The degree of achievement in the pursuit of our stated POs is evaluated in the formative assessment data collected for individual required courses, these results are aggregated by averaging each semester and recording important items in an evidence notebook. They are also aggregated on an annual basis and a 3-year rolling average basis to minimize statistical biases. The inputs from these formative evaluations show departmental trends that are periodically analyzed in faculty and curriculum committee meetings and improvements made promptly as required by the evidence.

For summative assessment, CASEE surveys are used to measure the degrees of achievements of the program outcomes. Here also, both direct and indirect measurement processes are used. We employ CASEE faculty surveys in the direct measurement method whereas the indirect approach uses the CASEE student surveys.

In addition to the quantitative assessment as described above, we receive qualitative feedback from students, alumni, and our industrial advisory board. We continuously use summaries of both qualitative and quantitative feedback to improve our courses, curriculum, and pedagogic approaches. We also use the classical employer surveys to assess the achievement of our program educational objectives (PEOs). In those surveys, individual employers are requested to indicate for each PEO whether they “strongly agree,” or “agree,” or “disagree,” or “strongly disagree” on whether we achieved the PEO. Achievement of a PEO is considered to be satisfactory if a majority of responders either “strongly agree” or just “agree.” In the survey we conducted just before the ABET evaluation all our PEOs have achieved a satisfactory or better level of performance.

CONCERNS: FACULTY, STUDENTS AND TRANSFERABILITY AND SUSTENAIBILITY OF THE REFORMS

The unusual circumstances of starting a new Department at the same time that innovation was being sought, brought advantages and disadvantages to many aspects of the creation. It did facilitate some aspects since all faculty members were newly hired and they were advised of the philosophy of the program as part of their interview process. There were disadvantages because we had no reference as to whether we were doing better or not. An overarching concern was the size of the faculty (only five in the first year) and the student body (some 40 students signed up for the new program). Fortunately the faculty was very adaptable to the construction and laboratory setup and felt a sense of fellowship that goes with the excitement of initiating something new.

It has been clear all along that while the specific details of the courses and project experiences might or might not be transferable, the three fundamental aspects were: a cognitive and learning style emphasis, a cost consciousness and entrepreneurship awareness and a strong active learning orientation throughout the curricula. While we cannot claim credit for these approaches, since they are commonly accepted today, they were certainly innovative during our planning activities in 2003. We know that we have influenced universities and junior colleges in the region and we have interacted nationally in conferences and workshops. Our syllabi and website for the DLR project is a nationally available resource. Our new approaches utilizing a blended education approach with Blackboard Vista and Turning Point are oriented to facilitate sustainability by reducing some of the recordkeeping required and trading any new burden for greater project interaction during approximately half of the L2L course and no less than one fifth of other project courses. Integrating Blackboard Vista and the Turning Point "clicker' software presented some difficulties in record keeping that are now mostly resolved. The sequence of eight projects culminates with a two semester senior project.

Given that our program grew gradually in faculty (currently eleven) and student body (approximately 250 undergraduates) we were not immediately faced with a culture that resisted change or was so large that adaptation of the project orientation was infeasible. We have observed, as expected, that the DLR philosophy is more difficult and costly to implement in larger well-established institutions. Practically all faculty members, including the junior faculty, participate at one time or another in the time-consuming process of project evaluation. Because of the original nature of the projects, there are no conflicts but reinforcements with the research interests of the faculty members. Important and valuable experiments in engineering education are the creation of new departments such as the Department of Engineering Education at the Virginia Polytechnic Institute [29] and new innovative freshman courses such as the one initiated at the New Jersey Institute of Technology [30], particularly in light of the unrealized high expectations from the Engineering Coalition Program. We have made presentations at the ECEDHA meetings, most recently in 2010 at the association's annual meeting in Florida [34]. The convergence of project orientation with greater student success and motivation, supported by technicians and graduate assistants, was the most popular approach presented at that meeting for sustainability. Transferability was not an issue because local industry lends a flavor to the most likely projects to undertake. However, the philosophy of viable oral and written project presentations and how to evaluate them needs to be refined to make the process somewhat less labor-intensive. Impact and motivation, not only at the freshman level but also for upper division courses, are best helped by the students themselves working collaboratively in teams.

An interesting aspect that seems to facilitate transferability and ease the burden of keeping the instrumentation up to date is the conduct of experiments via the Internet for complex inter-institutional collaborative projects. Our Texas Environmental Observatory (TEO) is an example of this approach used in the EE department [31].

CONCLUSIONS

The educational approach of the whole program and the innovative ways taken are intended to dynamically change, adopting the best themes, practices and methodologies from successful programs to motivate and orient future EE students.

The DLR project provides the blueprint for the design and continuous evolution of our curriculum with a focus on L2L, entrepreneurship, and project-based learning. Support from the mathematics and management departments as well as faculty enthusiasm in developing project and classroom courses contributes to the success of the program. The program has attracted and retained a broadly diversified student population consisting of 24 women, 41 African Americans, 15 Hispanic and three Native Americans representing approximately forty-five percent of the student body. Although female enrollment in EE varies widely among institutions, when we compare our female enrollment with other better established programs ([46], [47]) we find that our female undergraduate enrollment ratio of 12.7% is slightly above the (~12%) national average for accredited EE programs. This is particularly remarkable for a relatively new program, with an innovative bent. However, when surveyed, students report that the projects motivate them and enhance their understanding of engineering concepts. We believe this is critical to retaining students of both genders and all ethnicities in engineering.

A project-based curriculum is expensive in terms of money for equipment updates, human resources and time. The time requirement has been a particular problem in recruiting and incorporating industrial adjuncts into the program. Faculty intensiveness of this program is exacerbated by lack of competent technician assistance during the formative years. More effort is needed in this area so that students can be exposed to current industrial perspectives and practices.

Regardless of the costs noted above, the faculty and the students have embraced the program's goals and objectives and have implemented the core principles throughout the curriculum. The positive outcomes related to student achievement and retention as well as faculty acceptance of the project-based instructional model should help ensure program sustainability. It is encouraging to note that the program is well received by students and industry, and most of our graduates are employed in high-tech industries, with the remaining pursuing graduate studies. Since the inception of the program to the submission of this paper (graduating its first students in December 2009) there have been 32 students graduating at the BS level. Of those 24 are currently employed by industry, 2 are employed by the government and 6 have continued their education at the graduate level. Of the latter 6, there are 2 currently enrolled in a doctoral program.

We have been able to establish a continuous improvement process based on the qualitative and quantitative assessment data as discussed above. We prepared ABET documentation with substantive assessment data in support of ABET criteria 2, 3, and 4, and requested ABET for an evaluation visit in Fall 2009 which resulted in being accredited in 2010. We feel that our program is a great success because of its foundation on L2L, project-based learning, and its continuous improvement process based on well-designed and standardized assessment methodologies adopted by the entire faculty. The flavor of our four-year program permeates the undergraduate years with concern for the student in making him/her a more efficient learner and a more enthusiastic and organized society-conscious engineer. In conclusion, the UNT EE program prepares the students in developing outstanding abilities in project based learning, understanding of business practices, and awareness of the need for life-long learning

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support received from the National Science Foundation DLR grant NSF-0431818. We also acknowledge the contributions from Jon Young, Professor, College of Education, Yomi Adamo, Shengli Fu, and Xinrong Li from the Department of Electrical Engineering for their active participation in developing several lecture and project courses. Due to the time-intensive nature of the project courses, several past and present graduate students have made invaluable contributions that culminated in the success of project courses.

In an indirect but intellectually influential manner we are indebted to the work of Richard Felder [24], [25], [26] recognized for his pioneering work on learning and teaching styles and his inspiration to assist students through faculty to learn better and more. The foundational work of Benjamin Bloom and the analogy of its cognitive pyramid with the engineering design process are also to be noted as a new reassurance for engineering designers.

The anonymous reviewers are also thanked for improvements resulting from their suggestions.

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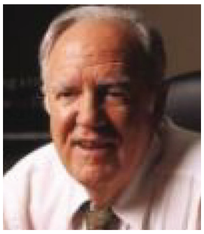

Oscar N. Garcia is currently Professor of Electrical Engineering after five years as Founding Dean of the College of Engineering at the University of North Texas from 2003 to 2008. Previous to this post he was NCR Distinguished Professor and Chair of the Department of Computer Science and Engineering at Wright State University from 1995 to 2003 after serving as Program Director of Interactive Systems at the National Science Foundation for four years. During that time he was also Professor of Electrical Engineering and Computer Science at The George Washington University. He has served as President of the IEEE Computer Society and for two terms in the Board of Directors of the IEEE. He was also Founding Chair of the Computer Science and Engineering Department at the University of South Florida where he served for fifteen years. He is a Life Fellow of the IEEE, a Fellow of the AAAS, a Centennial Medal recipient of the IEEE, an IEEE Third Millennium Medal recipient, a recipient of a Centennial Certificate of the ASEE and a recipient of the Richard E. Emberson IEEE Service Medal and the Richard E. Merwin Award of the Computer Society. He holds BSEE and MSEE degrees from NCSU and a PhD in EE from the University of Maryland. He is a registered Professional Engineer in the State of Texas.

Murali R. Varanasi received the B.S. degree in physics from Andhra University in 1957 and the D.M.I.T. degree in electronic engineering from Madras Institute of Technology, India, in 1962. He received the M.S. degree in 1972 and the Ph.D. degree in 1973, both in electrical engineering from the University of Maryland, College Park. He is currently serving as Professor and Chair of the Electrical Engineering Department, University of North Texas, Denton. His prior academic service includes faculty positions at Old Dominion University, Norfolk, VA, and the University of South Florida, Tampa, where he is Professor Emeritus. He has also served as Senior Scientific Officer at the Defense Research and Development Laboratory and later as a Member of the technical staff at Computer Sciences Corporation and Program Director at the National Science Foundation. Dr. Varanasi is an active participant in the IEEE Computer Society and served as Vice President of Educational Activities. He is also serving as Past-President of CSAB and member of the Board of Directors of ABET. He is the recipient of the Richard Merwin Award from the IEEE Computer Society and IEEE Third Millennium medal.

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Parthasarathy Guturu had more than seven years of experience in industrial R&D and ten years of research and teaching experience in academia abroad, prior to joining of the EE department at UNT as a faculty member. His achievements in the telecommunications industry include three patented innovations, which have also been extended and published as research articles in IEEE journals. He has published over 50 journal and conference papers. After joining the faculty of Electrical Engineering department at the University of North Texas (UNT), Denton, he has continued with his transformative research and publication agenda. He has contributed to the development of its innovative curriculum and transformative educational initiatives (TIIs) for which he was awarded the Provost's TII fellowship consecutively for two years since its establishment.

APPENDIX A

LEARNING TO LEARN (EENG 1910 PROJECT I) SYLLABUS

Course Description: 2 hours. Learning to Learn (L2L) is based on sound cognitive and pedagogical techniques that improve learning outcomes and make lifelong learning habitual. Students develop an understanding of how electrical engineering is learned and how we can facilitate and encourage the lifelong learning process. Topics covered include consciousness and self-awareness, metacognition, learning styles, memory, language, reading, writing, problem solving, creativity and biology of learning.

Course Purpose: Students need to take responsibility for their own learning. Not all classes or instructors are going to be able to meet all possible individual learning needs of each student. This class is designed to provide students with an opportunity to think about how they best acquire information and learn it on their own. Once students understand their strengths and weaknesses they can organize information and develop strategies that will help them learn content in their courses.

Student Responsibility: As part of this course you will learn to work in project teams in class in an interactive environment and also outside class in your projects. The success of any project team relies on the dependability of each of its members. The expectations of the instructor team for this course include this level of dependability. If this expectation is not met, by a single student, a policy will be implemented wherein absences, tardiness or lack of participation will impact individual grades.

COURSE OUTLINE

Unit 1: INTRODUCTION AND LEARNING STYLES

- Course Orientation
- Blackboard Vista http://ecampus.unt.edu/
- Learning Styles
- Activity: Learning Styles Inventory and Analysis

Unit 2: PROFESSIONALISM AND ETHICS

- Overview of course components
- Student Resources at the Discovery Park campus
  —Library, computer labs
- Student Organizations Presentation
- Professionalism and Ethics
- Activity:
  —IEEE Student Organization discussion
  —Team Building Exercise
- Assignment: IEEE Code of Ethics

Unit 3: KNOWLEDGE/COMPREHENSION/APPLICATION

- Bloom's Taxonomy
- Knowledge representation
- Introduce cognitive framework
- Team building and Sensors Lab Mini-Project I (Orientation)
- Activity: Work on mini-project I

Unit 4: ANALYSIS/SYNTHESIS/EVALUATION

- Guidance on preparing presentations and writing reports
- Activity: Teamwork: Preparing presentations and writing reports for Mini-project I

Unit 5: INSPIRED TO LEARN

- Self-motivation and student responsibility
- Activity: team presentations of Mini-project I
- Unit 6: DESIGN THINKING
- Process of Engineering design
- Assignment: Design
- Start Mini-Project II

Unit 7: LOGICAL THINKING/READING/WRITING

- Concept maps [32] (See example in Figure 2.)
- Technical reading
- Graphic organizers
- Technical writing format
- Assignment: Read technical paper
- Activity: writing reports and presentations Mini-project II
- Assignment: Analysis of Technical paper Article using graphic organizer

Unit 8 PROBLEM SOLVING/CREATIVITY

- Activity: presentations Mini-Project II
- Unit 9 EFFECTIVE COMMUNICATION
- Verbal Communication
- Written Communication
- Review of NASA information (Q&A)
- Activity: Speaking within groups (topic provided)
- Assignment: Write NASA report
- Start working on Mini-project III

Unit 10: CRITICAL THINKING

- Mental process: analysis and evaluation of statements
- Meanings of statements and terms used in papers and presentations
- Applies to both verbal and written communication
- Reasoning carefully and evaluating information to:
    - reach a conclusion
    - answer a question
    - or solve a problem

- Activity: Apollo Moon Landings, Global warming
- Working on Mini-project III

Unit 11: GLOBAL THINKING (see details in Appendix D as an example of a lesson)

- Taking into account knowledge of
  - Planet and International – across countries - the world
  - How does the world work?
- Across professional fields and academic disciplines
  - Physical, biological, environmental
  - Engineering: socio-technical
- Prepare for a globalized workforce
  - Careers in different regions of the world
  - Work in a variety of cultural contexts
  - Products and services that have global effects and implications
- Presentations of Mini-project III

Unit 12: ENGINEERING, SOCIAL AND CONTEMPORARY ISSUES (see Appendix D)

Unit 13 FINAL PROJECT PRESENTATION AND REPORTS

APPENDIX B

Relationship of Course Learning Objectives (CLOs) to ABET's Program Outcomes (POs) for the course EENG 1910 "Project I: Learning to Learn":

	CLO-1	CLO-2	CLO-3	CLO-4	CLO-5	CLO-6	CLO-7
PO-3(ABET 3c)		X					
PO-4(ABET 3d)				X			
PO-5(ABET 3e)		X					
PO-6(ABET 3f)			X				
PO-7 (ABET 3g)					X		
PO-8 (ABET 3h)						X	
PO-9 (ABET 3i)	X						
PO-10(ABET 3j)							X

Criterion 3. Expected Program Outcomes (POs) also known as "a-k".

Engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs

(d) an ability to function on multi-disciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

APPENDIX C

UNDERGRADUATE ELECTRICAL ENGINEERING CURRICULA

The documentation of the courses and graduation requirements for an undergraduate degree from the Department of Electrical Engineering at UNT is best found in the published catalogs. Catalogs are not only available in hard copy but are published electronically in [35]. The current undergraduate catalog is listed in [36] and the previous ones are archived in [37]. Minor changes, news or additions during the course of the year are listed in the departmental web site [38] because the courses have been subject to continuous improvement since its planning days [5].

APPENDIX D

ENGINEERING, SOCIAL AND CONTEMPORARY ISSUES

This is an example of the topics covered in one of the important lectures in L2L relating Engineering to Social and Contemporary Issues.

Which among the following do you believe is the best concept of global thinking?

What is global thinking?

Engineering education aims to:

We have come a long way in visualizing the Earth

The Big Blue Marble

How would you best be prepared for a global enterprise life?

Climate: related to agriculture, commerce, and quality of life (HVAC)

Gaia: the organismic view of the Earth

From the Dallas Morning News: April 22 is Earth Day (*www.earthday.net/*)

Human society: trade and politics

What does it mean that "the world is flat"? Is it? In what sense?

Time Zones: can help or hinder work hours

Time Zones

Languages: the Tower of Babel Do handheld translators help?

Languages and cultureshttp://www.ethnologue.com/

Languages

Skills for global thinking

What is Globalization?

Globalization: effects

Globalization: controversy

Globalization not new: from the Phoenician Mediterranean trade to the Silk Road and beyond

Outsourcing: a contemporary issue arising from communications and travel technologies, energy and educated human resources in a "flat" world

Some Outsourcing Factors

Outsourcing: in Engineering

Growth and Poverty Reduction

Globalization and Economy Links: a contemporary issue

Carbon footprints and Global Warming

The global communications and electronics industries: social and political issues

Even the supply and assembly of parts is global!World distribution of US owned semiconductor assembly plants (1988)

Summary of Global Trends

What is the most important of previous summary trends? Click

APPENDIX E

BRIEF DESCRIPTION OF THE EIGHT PROJECT COURSES

The progressive complexity of the projects should be noticed, as well as the allocation of two credit hours to each of the first six courses and three credit hours to each semester of the Senior Design Project. The fact that increasingly open-ended projects are a strong part of the curriculum is a hallmark of the program.

1910. Project I: Learning to Learn. 2 hours. Learning to Learn (L2L) is based on sound cognitive and pedagogical techniques that improve learning outcomes and make lifelong learning habitual. Students develop an understanding of how engineering and computer science are learned and how we can facilitate and encourage the lifelong learning process. Topics covered include consciousness and self-awareness, metacognition, learning styles, memory, language, reading, writing, problem solving, creativity and biology of learning.

1920. Project II: Introduction to Electrical Engineering. 2 hours. Engineering design project life cycle: requirements specification, architectural model/concept generation and evaluation, feasibility study, functional decomposition, design, testing, and maintenance. Principles for the design of a reliable, robust, maintainable and extendable system. Various levels of testing. Teams and teamwork, project management basics, tips for oral and written presentations, and an overview of ethical and legal issues. Introduction to Labview, MATLAB, VHDL and Spice. Implementation of small projects using these softwares. Project reports and oral presentations.

2910. Project III: Digital System Design. 2 hours. Digital system design projects that provide students substantial experience in logic analysis, design, logic synthesis in VHDL, and testing. Project documentation including all the phases of project cycle from requirement analysis to testing as well as a project presentation providing the students an opportunity to enhance their communication and presentation skills, are essential components of this course. Instructor may choose to include a mini-project for breadboard implementation with discrete components as a part of this course. Prerequisite(s): EENG 2710 (may be taken concurrently). May be repeated for credit with consent of instructor.

2920. Project IV: Analog Circuit Design. 2 hours. Students learn to use basic electrical engineering lab equipment, to build and test simple circuits in the lab and to design and analyze circuits using CAD software tools. Includes simulation and design experiments and a final comprehensive design project to complement the circuit analysis course. Prerequisite(s): EENG 2610. May be repeated for credit with consent of instructor.

3910. Project V: DSP System Design. 2 hours. To study basic theory and applications of modern digital signal processing, to learn basic theory of real-time digital signal processing, and to develop ability to implement and simulate digital signal processing algorithms using MATLAB and on real-time DSP platform. Prerequisite(s): EENG 2620.

3920. Project VI: Modern Communication System Design. 2 hours. Students are required to design electronic communication systems with electronic devices such as MOS transistors, capacitors and resistors. Topics include LC circuits and oscillators, AM modulation, SSB communications and FM modulation. Prerequisite(s): EENG 3520 (may be taken concurrently).

4910. Project VII: Senior Design I. 3 hours. Designing a wireless communication system or another electrical engineering system based on CADENCE or other software. This project aims to solve a practical engineering problem that meets ABET design criteria. Prerequisite(s): EENG 3810, 3910 and 3920; consent of instructor.

4990. Project VIII: Senior Design II. 3 hours. The capstone senior design course is a comprehensive electrical engineering design course. Students may choose a design topic in VLSI, communications, signal processing or any other relevant electrical engineering area. Substantial design work is required for passing this course. Prerequisite(s): EENG 4910.

APPENDIX F

EE COURSES IN THE PROGRAM

The program's titles of the nine required EENG lecture courses (for a total of 33 credit hours with the two elective courses) are listed below. The description may be found in the present and archived catalogs [36] and [37]:

2710. Digital Logic Design. 3 hours.

2610. Circuit Analysis. 3 hours.

2620. Signals and Systems. 3 hours.

3510. Electronics I (Devices and Materials). 3 hours

3410. Engineering Electromagnetics. 3 hours.

3710. Computer Organization. 3 hours.

3520. Electronics II. 3 hours.

4710. VLSI Design. 3 hours.

4810. Computer Networks. 3 hours.

To facilitate the offering of broad undergraduate elective choices we also provide four flexible courses:

4010. Topics in Electrical Engineering. 3 hours

4900. Special Problems in Electrical Engineering. 1–3 hours.

4920. Cooperative Education in Electrical Engineering. 1–3 hours.

4951. Honors College Capstone Thesis. 3 hours.

APPENDIX G

MULTIPURPOSE (UNDERGRADUATE PROJECT/GRADUATE RESEARCH) LABORATORIES

The listing of these laboratories is important as it shows the broad scope of the project-orientation of the curriculum beyond the freshman first course on L2L.

Analog, RF, and Mixed-Signal Design Laboratory: The RF and Microwave laboratory will support teaching, research and development of RF and microwave systems, integrated circuits, and devices. Researchers in this laboratory will design, fabricate, and test new microwave circuits including printed circuit boards (PCB), Silicon Monolithic Microwave Integrated Circuits (Si-MMIC), RF-MEMS and Radio Frequency Integrated Circuits (RFIC). They will also be able to design and integrate antennas with MMICs and RFICs.

Autonomous Systems Laboratory: Research in this laboratory focuses on information assurance, decision making, and video communications aspects in autonomous systems such as unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs). This laboratory consists of infrastructure and simulation tools necessary to develop protocols for autonomous systems and analyze their performance. The laboratory also includes several indoor and outdoor robots to develop and test decentralized decision making and task scheduling algorithms. The infrastructure also includes a wireless video sensor network platform suitable for simulating applications such as video surveillance.

Communications and Signal Processing Laboratory: The Communication and Signal Processing Laboratory (CSPL) focuses on design and development of advanced communication techniques to provide efficient and robust information transmission over wired and wireless networks. Working in concert with academia and industry partners, CSPL is dedicated to research on coding, information theory, encryption, wireless networking, and software defined radio.

Computer Aided Design (CAD) Laboratory: The CAD laboratory supports teaching and high-quality research activities related to Analog, Digital, Mixed signal, VLSI/SoC (System-on-a-chip) design, Test and Test verification. The laboratory will support teaching and research activities by providing state-of-the-art software tools such as Cadence, Xilinx, LabVIEW, MATLAB, MultiSim, Advanced Design Systems, Mentor Graphics etc.

Speech, Music, and Digital Signal Processing Laboratory: Different acoustic aspects are studied experimentally in this laboratory. They include speech (production, perception, transmission, analysis and synthesis, recognition, speaker identification), ultrasound, hearing prosthetics, music (analysis, synthesis and transcription) and management of acoustic signals with applications of digital signal processing methods and devices.

Vision, Robotics, and Control Systems Laboratory: The main goal of this laboratory is to support research in the areas of pattern recognition, image processing, computer vision, computational intelligence, robotics, and allied areas. This laboratory consists of infrastructure and simulation tools for computer vision and pattern recognition applications and control systems design.

Wireless Systems and Sensor Networks Laboratory: The Wireless Systems and Sensor Networks Research Laboratory focuses on system-level issues that are critical for the design of high-performance wireless networks and intelligent sensor networks. Current research topics include energy efficient networking protocols for distributed sensor networks, experimental and theoretical study of wireless system performance, statistical and real-time signal processing, measurement and modeling of wireless channels, optimum network deployment and connectivity, and development of sensor networks for environmental monitoring applications.